ENERGY GENERATION AND AMPLITUDE OF THERMOMAGNETIC WAVES IN THE CONDUCTING MEDIUM

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ABSTRACT

In article the thermomagnetic waves in the conducting medium are theoretically studied. The frequencies of these waves are obtained. The amplitude and conditions of radiation by media are determined in the first approximation.

Keywords: energy generation, thermomagnetic waves, conducting medium, frequency,

I. INTRODUCTION

The variable magnetic field appears in the solid, in which the temperature gradient ∇T takes place and this leads to the appearance of the thermomagnetic waves. These thermomagnetic waves propogate into longitudinal $\vec{k} // \vec{\nabla} T$ or the transversal $\vec{k} \perp \vec{\nabla} T$ ($\vec{k}$ is the wave vector) directions [1]. If the propogation velocity of the thermomagnetic waves is comparable with the sound velocity in the solid, then spectrum of the magnetoacoustical waves can significantly change. If there is external magnetic field, then the picture changes. Many works [2] are dedicated to the investigation of the longitudinal and transversal thermomagnetic waves into crystals. The frequency ω and wave vector $\vec{k}$ of these waves had been found in these works. In the given paper we will show the results of the theoretical investigations for the determination of the amplitude of the thermomagnetic waves in the anisotropic crystal.

II. MAIN PART

The equation for the electric field in the presence of the external magnetic field in the anisotropic solid have the form:

$$E_i = \eta_{ik} j_k + \eta'_{ik} \left[\vec{j}\vec{H}\right]_k + \eta''_{ik} (\vec{j}\vec{H}) H_k + \lambda_{ik} \frac{\partial T}{\partial x_k} + \lambda'_{ik} \left[\vec{\nabla} T \vec{H}\right]_k + \lambda''_{ik} (\nabla T H) H_k \quad (1)$$

Here η_{ik} - is tensor of reciprocal value of ohmic resistance, λ_{ik} - is value of the differential thermoelectromotive force, λ'_{ik} - is Nernst-Ettinghausen coefficient. The following Maxwell equations should be added to the (1).

$$rotE'_i = -\frac{1}{c}\frac{\partial H'_i}{\partial t}, \quad rotH'_i = \frac{4\pi}{c} j'_i + \frac{1}{c}\frac{\partial E'_i}{\partial t} \quad (2)$$

If all values have the character of plane monochromatic waves $(H', E', \nabla T') \sim e^{i(\vec{k}\vec{r} - \omega t)}$, $\nabla T' << \nabla T_0$ then from the (1-2) we obtain the dispersion equations for the determination of the frequency $\omega_{ik} = c\Lambda_{ik}\nabla T$ of the thermomagnetic waves under the condition $H' << H_0$, $E' << E_0$, (where E_0, H_0, ∇T_0 are constant values of the corresponding values). For the determination of the amplitude of the variable values $(H' = H'_0 e^{i(\vec{k}\vec{r} - \omega t)}, E' = E'_0 e^{i(\vec{k}\vec{r} - \omega t)})$ H'_0 and E'_0 and also $j' = j'_0 e^{i(\vec{k}\vec{r} - \omega t)}$, j'_0 ,we should lead (1-2) to the one nonlinear equation.

Because of the inconvenience we confine by the statement of the calculation at the obtaining of the nonlinear equation.

The study of the oscillation processes have the major importance for the most different fields of the physics and techniques. The point is, that the usual expansions over the degrees of the small parameters lead to the approximate formulae for the required values with members, harmonically dependent on the time, also secular members of the type $t^\alpha \sin\omega t$, $t^\alpha \cos\omega t$ and intensity of such members strongly increases and that's why these formulae are limited by the most short time interval. The nonlinear differential equations become the most powerful instrument of the investigation in the works of many scientists. We will mainly follow the method of A.N.Krilov, N.N.Bogolubov for the finding of the amplitude of current oscillation j'_0.

If we use this method for the solution of the nonlinear equation, which is obtained at the expansion of the E, H and ∇T.

$$(E, H, \nabla T) \sim (\ )_0 + \varepsilon A(t) + \varepsilon^2 B(t) + \varepsilon^3 C(t) + ... \quad (3)$$

then we obtain the Van-der-Pol equation for the oscillations of the electric field $\frac{E'}{E_0} = y$

$$\frac{\partial^2 y}{\partial t^2} + \omega_0^2 y = \varepsilon\Phi\left(y, \frac{\partial y}{\partial t}, \frac{\partial^2 y}{\partial t^2}, ...\right) \quad (4)$$

$\varepsilon << 1$ - is small parameter, which is easily defined by the expansion of (1-2) ω_0 is oscillation frequency at $\varepsilon = 0$.

From the formula (4) at ε=0 it is easy to find ω_0 at $\vec{k} // \nabla T$ and at $\vec{k} \perp \nabla T$.

At $\varepsilon = 0$, the solution (4) shows, that the transversal ($\vec{k} \perp \nabla T$) thermomagnetic wave appears in cubical crystal with the frequency

$$\omega_0 = \omega_{21} \frac{r-3}{5-r} \quad (6)$$

where r-is the whole number, $\omega_{21} = ck\Lambda_{21}\nabla T$ (c is velocity of light), it damps if $\omega_{21} > ck$, then the thermomagnetic wave appears in crystals $\nabla T > \frac{1}{\Lambda_{21}}$ with the frequency

$$\omega_0 = \frac{2\pi}{2\pi + \eta_{22}} \omega_{21} \quad (7)$$

With the increasing increment the state of cubic crystal is unstable, i.e. the current oscillates. The thermomagnetic wave doesn't exist in the longitudinal direction ($\vec{k} // \nabla T$) at $\omega_{ii} = \frac{ck}{4\pi}$, if $\omega_{ii} > \frac{ck}{4\pi}$ mixed wave propagates with the frequency

$$\omega_0 = \frac{c^2 k^2}{\pi^2(\omega_{22} + \omega_{33})}, \quad \omega_{ii} = c\Lambda_{ii} k \nabla T \quad (8)$$

The solution of the equation (4) under the conditions (6,7,8) is the amplitude of current oscillation j_0'.

However, as we need to find the current oscillation, then we necessarily should investigate the crystal state, when the unstability takes place. The solution of the nonlinear equation (4) at the values of the small parameter $\varepsilon << 1$ by the method N.N.Bogolubov-Mitroplosky [3] in the first approximation has the form:

$$\frac{da}{dt} = -\frac{\omega_0 \varepsilon}{2\pi} \int_0^{2\pi} \Phi \sin\psi \, d\psi, \quad \psi = \omega_0 t + \Theta$$

$$\frac{d\psi}{dt} = \omega_0 \left(1 - \frac{\omega_0}{2\pi uka} \int_0^{2\pi} \Phi \cos\psi \, d\psi\right) = \omega_1 \quad (9)$$

where u - is the velocity of the propagation of the thermomagnetic waves, a - is the oscillation amplitude of the magnetic field. Defining the type of the function Φ in each unstable state of crystal the dependence $a(E_0, H_0, \nabla T)$ and $\omega_1(E_0, H_0, \nabla T)$ are obtained. The crystal becomes of the source of the energy generation at the instable state.

III. CONCLUSION

Thus, the thermomagnetic waves in conducting medium are theoretically studied. The frequencies of these waves are obtained. The amplitude and conditions of radiation by media are determined in the first approximation.

REFERENCES

1. *L.E.Gurevich,* JETP, 44, 1963, 63.(in Russian)
2. *E.R.Gasanov,* NAS, TRANSACTIONS, XXIII, №5, 11(in Russian)
3. *N.N.Bogolubov, U.A.Mitropolsky.* Asymptotic methods in the theory of the nonlinear oscillations, Moscow, 1963, page 36-94 (in Russian)